Canada thistle control with mechanical cultivation, an organic method to control Canada thistle in 2 growing seasons

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Method Overview: starve Canada thistle roots for 2 years

1. Disk or plow the field in early spring to remove cover crop and prevent plant debris clogging cultivator sweeps
2. Sweep field when newly emerging Canada thistle shoots are 3-4 inches (7.5-10 cm) tall; continue throughout the growing season. This corresponds to a sweep frequency of 16-28 days. The delay in sweeping until shoots are 3-4 inches (7.5-10 cm) tall maximizes Canada thistle root carbohydrate depletion rate.
3. Approximately 90% of the Canada thistles root system is removed at the end of the first growing season of cultivation. Complete removal of Canada thistle underground root system is attained at the end of the second growing season.
4. In subsequent years, new Canada thistle plants may germinate from seed. These new seedlings must be removed to maintain field free of Canada thistle.

Introduction

Canada thistle (Cirsium arvense, Figure 1) is an invasive perennial broadleaf weed in United States and spreads mainly by underground roots.

Figure 1. Canada thistle in a bean field

Canada thistle biology

1. A particular Canada thistle root segment lives only 2 years (Rogers, 1928, Brenzil 2008). The entire root system can be starved to death by removing all above ground vegetation for 2 years
2. Severed roots expend energy to grow new shoots. A rapid shoot regrowth is simultaneously rapid root carbohydrate depletion. Use shallow cultivation to stimulate rapid regrowth. Deep cultivation delays shoot emergence resulting in slower regrowth and slower root carbohydrate depletion (Seely, 1952). Although Canada thistle roots may reach 15 feet deep (4.5 m), cultivating at 3-6 inches (7.5-15 cm) depth is sufficient

to deplete the root carbohydrate (Dersheid 1958, Hodgson 1977, Seely 1952, Wilson, 2009).

3. As soon as shoots appear above ground, they begin to photosynthesize but the rate of photosynthesis is less than amount of carbohydrate utilized for regrowth of new shoots. There is a net loss of root carbohydrate until sufficient leaf surface area is attained, at 1 foot tall (30 cm) or early flower bud formation (Dingman, 2006; Hodgson, 1968).
4. At the beginning of the growing season, the rate of root carbohydrate depletion is slow because few shoots. As young shoots reach 3-4 inches (7.5-10 cm) tall, the rate of root carbohydrate depletion is most rapid (Seely 1952) because large number of young growing shoots. As shoots reaches 1 foot (30 cm) tall or early flower bud formation, the root carbohydrate reserve is at its lowest point (Dingman 2006, Gover 2007, Hodgson 1968). However, the lowest carbohydrate reserve also corresponds to the slowest carbohydrate depletion rate; nearing zero and turning positive accumulation because of large leaf surface area for photosynthesis (Hodgson, 1968). There are 2 different critical points, rate and reserve:
    a. rate of root carbohydrate depletion is most rapid at 3–4-inch (7.5-10 cm) shoots height
    b. reserve of root carbohydrate is lowest at 12-inch (30 cm) shoots height, or early flower bud formation.
5. For the shortest time to eradicate Canada thistle, the frequency of cultivation is timed at the most rapid rate of root carbohydrate depletion, when shoots are 3-4 inch (7.5-10 cm) tall. Cultivation is repeated for a second growing season. For convenience of farm operation planning, cultivation frequency may be fixed at 21-28 days during the growing season instead of timing the shoot growth (Seely 1952).
6. For the fewest operations to eradicate Canada thistle by cultivation, mowing or foliar herbicides, the best time is at the lowest root carbohydrate reserve: 1 foot (30 cm) tall, or early flower bud stage. Repeat cultivation, mowing or herbicide treatment when regrowth shoots are 1 foot (30 cm); or at early flower bud formations (Dingman 2006, Gover 2007, Renz 2013). 'Alfalfa and tall forage grasses are the best competitors due to the repetitive cutting associated with these crops' (Wilson, 2009). However, the fewest operations mean longer time to eradicate Canada thistle, 3-5 years by mowing (Renz, 2013).
7. The above ground shoots exert apical dominance and inhibit root buds from sprouting. If cultivation does not completely sever the vertical shoots, there would be fewer new shoot regrowth, slower depletion of root carbohydrate and a longer time to eradicate Canada thistle. To starve the roots by mechanical cultivation, use overlapping sweeps and ensure complete severance of all shoots during each cultivation. Tandem disk is unsatisfactory (Derscheid 1959); there is an uncut center strip between the two sets of tandem disc. Depending on disk gang angle, the spacing between blades could allow vertical shoots to escape cutting. Depending on tractor ground speed, rotary tillers may have similar problem of incomplete shoots severance. Chiseling is unsatisfactory because it leaves many uncut shoots.

Control of Canada thistle with cultivation was described by Hodgson (1977):
'Food reserves in the roots …are normally at the lowest point of the year 4 to 6 weeks after emergence of the first plants (very early bud stage) in the spring…From 90 to 98 percent of a Canada thistle infestation can be eliminated by one season of cultivation begun at the low point of reserve and repeated every 21 days during the growing season. The remaining plants can be eliminated by continuing the cultivation a few times next spring…The first step is to plow and disk the land. Then cultivate 3 or 4 inches deep when new shoots appear. A duckfoot cultivator with overlapping sweeps is an efficient tool for this work. About 10 days after each cultivation

new shoots usually emerge, and another 10 or 15 days they are capable of furnishing food to the roots. The purpose of cultivating at 21-day intervals is to destroy newly emerging shoots just before they begin replenishing root reserves.'

Method

Control of Canada thistle is the Seely (1952) method: disk the field in early spring to turn under cover crop, then cultivate with sweeps when regrowth shoots are 3-4 inches tall (instead of early bud stage) and repeat cultivation when new regrowth shoot reaches 3-4 inches tall, continue throughout the growing season (instead of every 21 days).

1. Disc field in early spring to turn under cover crop and to prevent clogging of sweeps by plant debris. Cultivate with overlapping sweeps when Canada thistle shoots are 3-4 inches (7.5–10 cm) tall, continue throughout the growing season when regrowth shoot is 3-4 inches tall, in 16-28 day. Use shorter intervals between cultivation at the beginning of the season; longer intervals later in the season as the root carbohydrate are exhausted. Overlapping sweeps are mounted on a tool bar with 3-point hitch and run at 2–6-inch (5-15 cm) depth (Figure 2). Each cultivation consists of 2 passes at the beginning and switch to single pass later in the season. Two passes compensate for the varying depth of sweep cultivation due to tool bar mounted on 3-point hitch that rocks side to side as the tractor travels on uneven surface. Also, sweep blades were 'hard faced' with chrome alloy beads at the bottom edge of the sweep to increase blade life. The chrome bead increases blade thickness, resulting in long wearing dull blades that cannot be sharpen; instead of sharp blades that wear out quickly.

Figure 2. Sweeps mounted on tool bar

2. Continue sweep cultivation for a second year.

3. In subsequent years, new Canada thistle plants may germinate from seed (Figure 3). These new seedlings must be removed to maintain field free of Canada thistle

Figure 3. Canada thistle germinated from seed with shallow roots

Results
A farm located in Veneta, Oregon, USA was infested with Canada thistle and the thistle was removed by mechanical cultivation.

2011 to 2017 cultivations
The initial attempts at controlling Canada thistle were prior to review of the literature, and did not follow the method described above.

1. In September 2011, Canada thistles were dug by hand in a ½ acre (0.2 ha) plot using a narrow blade drain shovel to remove roots 16 inches (40 cm) deep. In 2012, a summer crop was planted, but hand digging of Canada thistle continued throughout the growing season. By September 2013, 6 Canada thistles were found. Canada thistle was removed by hand digging, starting in September and continue into the next 2 growing season.
2. In May 2014, a 5-acre (2 ha) plot was cultivated with point chisels and overlapping sweeps for 3 growing season, until October 2016. Point chisels were run at 10-16 inches (25-40 cm) deep; overlapping sweeps were run at 8 inches (20 cm) deep. After 2017 fall crop harvest, 2 Canada thistle plants were found. Canada thistle was removed in 4 growing season using both point chisels and overlapping sweeps. This site also had a small 100 sq ft (9 m2) patch of field bindweed (Convolvulus arvensis) that was eradicated along with the Canada thistle.
3. In May 2015, a 5-acre (2 ha) plot was cultivated with point chisels run at 16–20-inch (40-50 cm) depth for 2 seasons. After onset of fall rain, walk the field to dig out Canada thistle, repeat in 2016. By September 2017, over 100 Canada thistle plants per acre survived in the 5-acre (2 ha) plot. Canada thistle was not removed in 3 growing season using point chisel.

2016 to 2018 cultivations
A 9-acre (3.6 ha) site was cultivated with sweeps starting in the fall of 2016 and continued through 2017 and 2018. By October 2017, only 10 Canada thistle plants were visible in the 9-acre site. By October 2018 there were no visible Canada thistles. Beans were planted in 2019 and 2020 and the field was inspected for Canada thistles throughout the growing seasons. In 2019 approximately 100 young Canada thistle seeding were found and removed by hand digging. In the 2020 approximately 150 young Canada thistle shoots were found. Half of the 2020 Canada thistles were within 200 feet from the western edge of the field; the prevailing wind is from the west. This site also had 2 small (200 sq ft; 19 m2) patches of field bindweed at the start of the cultivation. The patches were reduced in size, along with the Canada thistle. Ten bindweed plants were found the third year (2019); 2 plants were found in 2020. Canada thistle root system was removed in 2 growing season, but there were seed grown thistles in subsequent years.

2018 to 2020 cultivations
To compare the efficacy of fall cultivation, half of a 10-acre (4 ha) section was cultivated after fall harvest in 2018, cultivation continued through 2019 and 2020; the remaining half commenced cultivation in spring 2019. In 2019, the entire field was disc twice to remove the cover crop. The first sweep cultivation was 8 May, 2019. Subsequently, the field was cultivated when Canada thistle shoots reach 3- 4 inch (7.5-10 cm) tall and continued until fall rain. At the beginning of 2020 cultivation, there was over 100 Canada thistle plants per acre visible. By August 2020, no Canada thistle was visible. There was no visually observable difference between the field with fall 2018 cultivation and the field without 2018 fall cultivation. The following pictures (Figures 4-11) were taken just prior to sweep cultivation in 2019.

Figure 4. 16 days after first sweep cultivation, prior to 2nd cultivation, 24 May, 2019

Figure 5. 20 days after 2nd cultivation, June 20

Figure 6. 21 days after 3rd cultivation, 4 July, 2019

Figure 7. 20 days after 4th cultivation, 24 July 2019

Figure 8. 20 days after 5th cultivation, 13 August 2019

Figure 9. 22 days after 6th cultivation, 4 Sept 2019

Figure 10. 22 days after 7th cultivation, 26 September 2019. Fall rain germinated winter weeds.

Figure 11. 22 days after 7th cultivation, close-up, 26 September, 2019

Discussion

Canada thistle has multiple layers of horizontal root, interspersed with deep tap roots, and upright shoots that arise from the horizontal roots (Figure 12).

Figure 12. Canada thistle horizontal root system

In spring, when upright shoots are cut, new shoots emerge below the cut (Figure 13). Emerging shoots utilize carbohydrate stored in the roots for its regrowth. After the shoot emerges above the soil surface, photosynthesis supply part of the carbohydrate required for shoot growth, but the stored root carbohydrate continues to supply nutrient for shoot regrowth until shoots are 1 foot tall, or at early flower bud formation (Dingman, 2006; Hodgson, 1968). Cultivation frequency was adjusted to 3-4-inch-tall shoots to maximize the carbohydrate depletion rate (as recommended by Seely, 1952); instead of early bud formation when the carbohydrate reserve is lowest and the rate of carbohydrate depletion is nearing zero, turning positive (as recommended by Hodgson, 1977).

Figure 13. Canada thistle re-sprouted below cut indicated by arrow

If shoots are cut just below the soil surface while keeping the multiple layers of horizontal roots and deep tap root intact, there will be many sites of shoot regrowth to deplete the tap root carbohydrate. If deep cuts are made, separating horizontal root from the tap root, there will be fewer sites for shoot regrowth to deplete its carbohydrate reserve in the deep tap roots. If shoots are cut above the soil surface by mowing, shoot regrowth will also deplete the root carbohydrate reserve until 1 ft shoot height or early flower bud formation. The most rapid rate of root carbohydrate depletion is with shallow cuts below the soil surface when new shoots reach 3-4 inch (7.5-10 cm) tall; the slowest depletion rate is with cuts above the soil surface at early flower bud formation.

Shoots that reach 4 inch (10 cm) tall are merely fast-growing shoots. Many slower growing shoots are at or below the soil surface (Figure 14). The abundance of these young shoots contributes to the rapid carbohydrate depletion rate when fast growing shoots reach 4 inches tall.

Figure 14. Foreground, young Canada thistle sprouts cut by sweeps; 3-inch-tall shoots on left, and shoots from below soil surface on the right. Background, field prior to cultivation, with shoots 3 inch tall or less.

Canada thistle was eradicated using shallow overlapping sweeps at 2–6-inch (5-15 cm) depth; when emerging shoots reach 3-4 inches (7.5-10 cm) tall; and sweep for 2 growing seasons. In subsequent years, Canada thistle can grow from seed and must be removed to maintain the

field free of Canada thistle. Small patches of field bindweed were also eradicated along with Canada thistle.

Literature review of Canada thistle control with cultivation

Recommended frequency of cultivation varied from 10 to 28-day intervals due to differences in plant growth rate at different locations with different climate and soil conditions. Whereas, cultivation frequency when shoot regrowth reaches 3-4 inches (7.5-10 cm) tall compensates for varying growing condition. The following literatures list the starting date, frequency of cultivation and depth, which are highlighted:

1. North Dakota: Lym, 2013. For perennial weeds including Canada thistle: *'Cultivate fields before the perennial species are 3 inches tall and repeat before regrowth reaches 3 inches tall until freeze-up.'*
2. South Dakota: Derscheid et al 1959. '*…perform the first operation with a plow if there is considerable plant residue. Equip the duckfoot cultivator with wide sweeps (12 to 24 inches) that overlap 3 or 4 inches…operate at a depth of 4 to 5 inches… little food is stored in the roots and root reserves are being used for plant growth for a period of 20 to 30 days… Cultivate every 3 weeks during good growing conditions and every 4 weeks during periods of dry, hot weather when the plants are growing less rapidly. This generally means that cultivations should be done at 3- week intervals during June and July and at 4-week intervals during August, September and October… A disk harrow is not a satisfactory implement… double disking with a tandem disk was unsatisfactory even when used every 2 weeks*'
3. Nebraska: Wilson, 2009. *'Cultivation has been used to starve the plant roots by repeatedly destroying new shoots. It should be started in May and continue up to two years at 10 to 15 day interval during the growing season… cut thistle off about three to four inches below the soil surface.'*
4. Idaho: Dingman, 2006. *'Carbohydrate reserves are depleted in the spring and at other times when new emerging shoots use energy from the roots…Little replacement of root reserves occur until plants are about 1 foot tall …Cultivation alone has been shown to control the perennial plants when tillage is started at flower bud time (when root energy reserves are low) and continued every 10 days through the season. To be successful, this practice must be repeated the next year.'*
5. Idaho: Seely, 1952. '*…Initial cultivations were made by plowing 6 inches deep when the Canada thistle was about 5 inches tall, and subsequent cultivations were made with a duckfoot field cultivator at a depth of 4-5 inches. Cultivation were continued until growth ceased in the fall…A 21-day interval gives an adequate margin of safety in the cultivation program …The frequency of cultivation [8 to 16 days after emergence] is not so critical with Canada thistle as it is with bindweed. It would appear to be desirable to use the same frequency of cultivation on both Canada thistle and bindweed where both weeds occur on the same field*'. A 21-day interval between cultivation is approximately 12 days after emergence of the bindweed with 6 inch vine; approximately 8 days after Canada thistle shoot emergence and 3 inch height.
6. Pennsylvania: (Gover et al, 2007). For herbicide treatment *'The most important opportunity for control is the fall when thistle is recharging its root system for the next growing season…Late spring, when thistle is at the bud-to-early-bloom stage is the second important opportunity for control.*'
7. Colorado: Rogers 1928. *'Under normal conditions roots of the Canada thistle live in the soil for two seasons…A root which is formed early in the spring will reach its full development the same summer, but probably will not produce flowering stalks. The shoots it sends up will have many leafy stems, and will assist in the accumulation of the reserve supply of food and energy to be used the next spring. These tops die down to*

the root in the winter…During the second season for the root, it produces large flower stalks. In the meantime young roots have been growing out from the old one, and have penetrated the soil in all directions. During the summer of 1929, therefore, the greatest activity of the 1928 root is reached. It quickly falls into decay after the death of the tops and in the spring of 1930 the root will be nothing but a dead black form with a shredded string in the center, which was the conducting tissue. Roots which are hindered by smothering or by other interference, do not follow this cycle so closely, and are usually longer lived because their normal development has been interrupted. '

Field Bindweed (Convolvulus arvensis)

In field where both Canada thistle and field bindweed occur, frequency of cultivation should be based on field bindweed.

Seely, 1952: '*Bindweed is a relatively warm weather plant and, in the Palouse [Idaho, USA] area, makes its most rapid growth during July and August. Growth is much slower in the spring months and somewhat slower in the fall than during mid-summer.*' [This is the reverse of Canada thistle, which makes its most rapid growth in spring, then fall and the slowest growth in July and August.]

'*… The most efficient time to start a cultivation program on bindweed was just as soon after harvest as possible. The most effective frequency of cultivation was 12 days after emergence of the bindweed* [corresponding to 6-inch-long vine]. *The best constant frequency of cultivation that was tested was every 21 days, but this was not so good as 12 days after emergence which averaged the same number of days between cultivations. The depth of cultivation [4 inch vs. 12-inch depth] was not an important consideration since deeper cultivation required less total cultivations but more time for eradication. It was concluded that cultivations should be made only deep enough to cut off all plants at each cultivation with the implements being used. October 1 was the best date to stop cultivation in the fall…*

No information was obtained on the proper depth of cultivation of Canada thistle, white top and Russian knapweed; but the similarity in the root system of these weeds and in those of bindweed would indicate that they would respond much the same. Apparently the major factor in the lack of efficiency of deep cultivation is that the rate of emergence is slower from deep than shallow cultivations; hence it requires a longer period of time to exhaust a given amount of reserves. This is probably characteristic of the type of root system; hence all of these weed probably would be eradicated more quickly with shallow cultivations than with deep ones… the length of time required for eradication varies with the amount of stored food available and the relative speed of exhaustion. Root samples taken on the four weed indicate that bindweed stored the largest amount of food. White top, Russian knapweed and Canada thistle follow in the order given. The empirical test indicated that when growing condition were similar approximately three season of cultivation were required for the eradication of bindweed and white top, about two for Russian knapweed and one for Canada thistle… Weather conditions appear to be the major factor in the length of time required for eradication with any particular cultivation schedule…'

Summary

Canada thistle has 2 vulnerable plant growth stages suitable for mechanical weed control.

1. Attack Canada thistle when its root carbohydrate depletion rate is greatest, during rapid regrowth with many new shoots: 3-4 inches (7.5-10 cm) tall. Use overlapping sweeps; run at 3-5 inches (7.5-13 cm) below the surface; approximately 21 days frequency; for 1 to 2 years. This method was used and found to be effective.
2. Attack Canada thistles when its root carbohydrate content is lowest. Mow when plants are at early flower bud stage, or 1 foot (30 cm) tall; integrate mowing schedule with

alfalfa or tall forage crop harvest; approximately 3 mowing per year for 3-5 years. This method was not evaluated.

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